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**ORNL
FOREIGN TRIP REPORT
TA 445114**

DATE: October 22, 2019

SUBJECT: Trip report for the annual meetings of the Working Party on Nuclear Criticality Safety and its Expert Groups (WPNCS)

TO: Angela Chambers, Nuclear Criticality Safety Program Manager, National Nuclear Security Administration / NA-511/GTN, Pantex Plant, PO Box 30020, Amarillo, TX 79120-0020

FROM: Kursat B Bekar

**MEETING:
TITLE** The annual meetings of the Working Party on Nuclear Criticality Safety and its Subgroups (WPNCS)

**MEETING:
LOCATION** Paris, FRANCE

**MEETING:
DATES** September 23-27, 2019

**ATTENDEES:
ON BEHALF
OF NCSP** Kursat Bekar, William Marshall, and Will Wieselquist

**MEETING:
BENEFIT TO
NCSP** The NEA nuclear science program helps member countries identify, develop and disseminate basic scientific and technical knowledge required to ensure safe, reliable and economic operation of current nuclear systems and to develop next-generation technologies. WPNCS, the Working Party on Nuclear Criticality Safety, is its one of the expert groups which deals with the technical and scientific issues related to criticality safety area, and it aims to exchange information on national programmes in this area and coordinate the activities of common interests to the international criticality safety community. It has several subgroups; each focuses on different technical issue in the criticality safety area.

Participation in the meetings of the WPNCS and its subgroups allows us to increase the awareness of the latest developments in modeling, simulation and analyses of the criticality safety problems, to be involved in decision making and planning related to the nuclear criticality safety, and to integrate the acquired information into future developments and advancements for the NCSP-sponsored radiation transport analysis tools within the SCALE code system. This definitely improves the code quality and

enlarges its application space to a broad class of problems related to the criticality safety applications. This is highly beneficial for NCSP since this program aims to provide supports for nuclear criticality safety applications with advance methods and state-of-the-art radiation transport tools. In addition to this, participation in each subgroup, contributing and leading the activities in each group also increases the international recognition of the ORNL and NCSP.

**MEETING
PURPOSE:**

The purpose of the meetings is to coordinate the activities in each subgroup, to discuss the progress in ongoing works which mainly focus on the computational benchmark problems designed to check the capability of the modeling and simulation tools and methods when performing criticality safety analysis, to discuss the issues and create new subgroups to deal with them, and to exchange information on various national programs on nuclear criticality safety.

**SITES
VISITED:**

ABSTRACT: This trip was planned to attend two meetings, 11th International Conference on Nuclear Criticality Safety (ICNC), and the annual meetings of the Working Party on Nuclear Criticality Safety (WPNCS) and its subgroups, and this report for the second week of my trip, WPNCS meetings.

WPNCs, the Working Party on Nuclear Criticality Safety, is one of the expert groups of the NEA nuclear science program, which deals with the technical and scientific issues related to criticality safety area. It has several subgroups; each focuses on different technical issue in the criticality safety area. Meetings of WPNCS and its subgroups help to coordinate the activities, allow exchanging information related to modeling, simulation, validation and analysis of the criticality safety applications.

In each subgroup, ongoing activities, which mainly focus on the computational benchmark problems designed to check the capability of the modeling and simulation tools and methods for criticality safety analysis, were discussed. Activities about fission source convergence tests and methods to address undersampling issues in Monte Carlo methods and codes, benchmark results and progress on the effect of temperature on reactivity predictions for PWR fuel, critical experiment correlations, MOX damp powders were discussed. In addition to these, in one of the subgroups, critical experiment needs to support safety analyses were also discussed.

A new subgroup (SG-8) was proposed to define a rating system for evaluations in the International Criticality Safety Benchmark Evaluation Project Handbook. ORNL lead subgroup was approved and will start the studies in next WPNCS meeting in 2020.

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REPORT OF FOREIGN TRAVEL

**Kursat B Bekar
Paris, France
October 22, 2019**

PURPOSE OF TRAVEL

The purpose of travel was to attend the meetings of the WPNCS and its subgroups to be involved in discussions, decision making, and planning related to the nuclear criticality safety, to increase the awareness of the latest developments in modeling, simulation and analyses of the criticality safety problems and use the acquired information for future planning, developments and advancements of the NCSP-sponsored radiation transport analysis tools (CSAS criticality safety analysis sequence, TSUNAMI uncertainty and sensitivity analysis sequence) within the SCALE code system.

Persons Contacted at WPNCS

I met several participants/delegates from different countries/organizations:

NEA: Shuichi Tsuda, Tatiana Ivanova
USA: Catherine Percher, John Bess, David Heinrichs, Chris Perfetti, Michael Rising
FRANCE: Isabel Duhamel, Coralie Carmouze, Axel Hoeffler
GERMANY: Fabian Sommer
UK: Paul Smith, Sonny Gan
SWEDEN: Dennis Mennerdahl
JAPAN: Yuichi Yamane, Kotaro Tonoike, Toshihisa Yamamoto

Itinerary

09/14/19 – 09/15/19	Travel from Knoxville, TN USA to Paris, FRANCE
09/15/19 – 09/19/19	Attend ICNC-2019 conference in Paris – see separate trip report
09/23/19 – 09/27/19	Attend WPNCS and its subgroups meetings;
9/23/2019	Analysis of past criticality accident (SG-4) The effect of temperature on the neutron multiplication factor for PWR fuel assemblies (SG-3)
9/24/2019	Blind benchmark on MOX damp powders (SG-2) On the definition of a benchmark on sensitivity/uncertainty analyses on used fuel inventory (SG-7)
9/25/2019	Experimental needs for criticality safety purpose (SG-5)

Statistical tests for diagnosing fission source convergence and undersampling in Monte Carlo criticality calculations (SG-6)

9/26/2019	Role of integral experiment uncertainties and covariance data in criticality safety validation (SG-1)
9/27/2019	WPNCs
09/28/2019	Travel from Paris, FRANCE to Knoxville, TN USA

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**ORNL
FOREIGN TRIP REPORT
TA 443028**

DATE: October 10, 2019
SUBJECT: Trip report for International Conference on Nuclear Criticality Safety
TO: Angela Chambers, Nuclear Criticality Safety Program Manager, National Nuclear Security Administration / NA-511/GTN, Pantex Plant, PO Box 30020, Amarillo, TX 79120-0020

FROM: Dr. William J. Marshall

MEETING: WPNCS and Related Subgroup Meetings
TITLE
MEETING: Boulogne-Billancourt, France
LOCATION
MEETING: September 23-27, 2019
DATES
ATTENDEES: William Marshall, Will Wieselquist, and Kursat Bekar
ON BEHALF
OF NCSP
MEETING: Participation in the WPNCS and its subgroups allows software developers and users
BENEFIT TO to maintain awareness of and participation in the latest developments related to
NCSP modeling, simulation, validation, and analyses of criticality safety models. Leadership roles and participation in the groups also enhance the prestige of the NCSP and its laboratories on the international stage.

MEETING The purpose of the meetings was to coordinate on-going work on a range of
PURPOSE: computational benchmark efforts related to various aspects of the analytical methods used in modeling and simulation codes for criticality safety analyses.

SITES
VISITED:

ABSTRACT: The trip to France had two distinct purposes and was split into two pieces: September 15-20 to attend the 11th International Conference on Nuclear Criticality Safety (ICNC) and September 23-27 to attend the subgroup meetings of the Working Party on Nuclear Criticality Safety (WPNCS). This trip report covers the second week and the WPNCS subgroup meetings.
WPNCS meetings allow interchange among different organizations performing research related to modeling, simulation, and validation of computer codes used for criticality safety analyses. A subgroup is also focused on critical experiment needs to support safety analyses. ORNL has taken on leadership roles in several of the subgroups which report to the WPNCS.

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REPORT OF FOREIGN TRAVEL

**William J Marshall
Paris (Boulogne-Billancourt), France
October 10, 2019**

PURPOSE OF TRAVEL

The purpose of the meetings was to exchange information on various on-going computational benchmark problems related to various aspects of modeling and simulation relevant to criticality safety, to discuss the creation of new subgroups to generate and study new problems, and to exchange information on various national programs on nuclear criticality safety. The benchmark problems discussed included source convergence/neutron clustering, critical experiment correlations, validation of damp MOX powder systems, and the effect of temperature on reactivity predictions for PWR fuel. A new subgroup (SG-8) was proposed and approved to generate a coarse rating system for evaluations in the International Criticality Safety Benchmark Evaluation Project Handbook. Finally, next year's WPNCS and subgroup meetings are scheduled for June 29 – July 3, 2020.

Persons Contacted

NEA: Shuichi Tsuda, Tatiana Ivanova, Franco Michel-Sendis

IRSN: Isabel Duhamel, Ludyvine Jutier, Nicholas Leclaire

CEA: Coralie Carmouze, Marion Tiphine

GRS: Maik Stuke, Fabian Sommer

Wood: Paul Smith

Others: Dennis Mennerdahl, Axel Hoeffler, Sven Tittlebach, Marcel Tardy, Yuichi Yamane, Kotaro Tonoike, Toshihisa Yamamoto, Michael Rising, Catherine Percher, John Bess, Sonny Gan, and others

Itinerary

9/14/2019	Depart Knoxville, TN
9/15/2019	Arrive Paris
9/15-9/19/2019	Attend conference in Paris – see separate trip report
9/19-9/20/2019	Participate in technical tour of ORANO La Hague Fuel Cycle Facility – see separate trip report
9/23-9/26/2019	Attend subgroup meetings of the Working Party on Nuclear Criticality Safety (WPNCS)
9/27/2019	Return to Knoxville, TN
NEA Headquarters, Boulogne-Billancourt, France (day-by-day agenda)	
9/23/2019	Analysis of Past Criticality Accident (SG-4) The Effect of Temperature on the Neutron Multiplication Factor for PWR Fuel Assemblies (SG-3)
9/24/2019	Blind Benchmark on MOX Damp Powders (SG-2) On the Definition of a Benchmark on Sensitivity/Uncertainty Analysis on Used Fuel Inventory (SG-7)
9/25/2019	Experimental Needs for Criticality Safety Purpose (SG-5)

	Statistical Tests for Diagnosing Fission Source Convergence and Undersampling in Monte Carlo Criticality Calculations (SG-6)
9/26/2019	Role of Integral Experiment Uncertainties and Covariance Data in Criticality Safety Validation (SG-1)
9/27/2019	WPNCs

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**ORNL
FOREIGN TRIP REPORT
TA 446004**

DATE: 2019-10-01
SUBJECT: Trip Reports for 2019 ICNC and WPNCS
TO: Angela Chambers, Nuclear Criticality Safety Program Manager, National Nuclear Security Administration / NA-511/GTN, Pantex Plant, PO Box 30020, Amarillo, TX 79120-0020

FROM: Will Wieselquist

MEETING: International Conference on Nuclear Criticality Safety (ICNC) 2019 and Working
TITLE Party for Nuclear Criticality Safety (WPNCS) at OECD/NEA
MEETING: Paris, France
LOCATION
MEETING: 09/14/2019 – 09/28/2019
DATES
ATTENDEES: Will Wieselquist
ON BEHALF
OF NCSP
MEETING: The benefits to NCSP include, as director of the SCALE code system, I am
BENEFIT TO more easily able to address the needs of the community if I am current with
NCSP domestic and international issues in nuclear criticality safety and able to communicate in person with the relevant parties. Also, mainly with regard to the week at WPNCS, this visit enables me to participate in decision making and planning related to nuclear criticality safety within the working party, and integrate this information into priorities for development within the SCALE code system.

MEETING Attend ICNC and WPNCS. Participate in discussion and planning.
PURPOSE:

SITES Week 1: ICNC Conference Center
VISITED: Cité des sciences et de l'industrie
30, avenue Corentin-Cariou
75019 Paris

FRANCE

Week 2: OECD/NEA Headquarters
46, quai Alphonse Le Gallo
92100 Boulogne-Billancourt
FRANCE

ABSTRACT:

This trip report documents two weeks spent in Paris supported by NCSP: the first at the ICNC conference and the second at the WPNCS meeting. The agenda included describes the most useful and relevant information gained. My main goal as the new director of the SCALE code system was to understand better the current issues in criticality safety so as to direct our efforts to better support this specific community of users. I have much more experience in the reactor physics side of things so this was a great opportunity to understand another aspect of nuclear engineering.

The following are my action items resulting from this trip.

- Develop a way to assess the performance of WHISPER vs. SCALE methods to more clearly highlight advantages/disadvantages. Currently, I think the ideal way to compare methods is to remove a single case from the validation set, treat that case as an application, predict the bias in that case from all others, and compare to the true bias.
- Develop documentation/examples/training/additional tools to make the SCALE bias prediction easier to use. Is this a better connection to DICE? What are the needed tools?
- New nuclear data evaluations such as Thermal Scattering Laws for ice and and Gadolinium isotopes need to have proper SCALE performance assessments.
- Results for Sub-Group 3 at WPNCS on understanding effects of ice on transport and storage calculations should be presented, perhaps in a clarified form, to SCALE users.
- Source convergence analysis and acceleration techniques in production SCALE need to be more clearly documented—they may be comparable to **new, unreleased** techniques in MCNP but most SCALE users do not know about them. Additional convergence diagnostics should be investigated.
- I will lead a new Sub-Group 8 to better categorize benchmarks by usefulness for a specific purpose and collect more information on ICSBEP benchmarks, especially from experts, to disseminate to the entire community.

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REPORT OF FOREIGN TRAVEL

**Will Wieselquist
Paris, France
09/14/2019 – 09/28/2019**

PURPOSE OF TRAVEL

The purpose of this travel was to, as director of the SCALE code system, understand current domestic and international issues in nuclear criticality safety. By communicating in person with practitioners and researchers and attending their presentations, I am more easily able to understand the needs of the criticality safety community, especially given my background in reactor physics, which would not normally bring me to the ICNC conference. Also, mainly with regard to the week at WPNCS, this visit enabled me to participate in decision making and planning related to nuclear criticality safety within the working party, and integrate this information into priorities for development within the SCALE code system.

Persons Contacted

Contact was limited to conference attendees at ICNC and working party participants at WPNCS. Some new relationships established in a criticality safety context follow.

- John Bess
- Catherine Percher
- Axel Hoefer
- Sonny Gan
- Paul Smith
- Stephane Evo
- Coralie Carmouze
- Fabian Sommer
- Michael Rising
- Luiz Leal
- Josh Hykes
- Dennis Mennerdahl

Itinerary

09/14/19 – 09/15/19 Travel from Knoxville, USA to Paris, France

ICNC, Paris, France (day-by-day agenda)

09/16/19 morning Attended ICNC Plenary. Gained an appreciation for criticality safety needs in front-end and back-end, including storage.

09/16/19 afternoon Attended Nuclear Data (Track 2). Thermal scattering law (TSL) data was the subject of many talks. Interesting results below.

- Including TSL data for U and O in UO₂ can decrease reactivity by 100 pcm.

	<ul style="list-style-type: none"> • New updates of U234, U236 (important impurities in some systems) may have impact on criticality safety calculations. • There is little impact of TSL on reactivity swing observed in depletion calculations between different data libraries (ENDF/B vs. JEFF).
09/17/19 morning	Attended Sensitivity Uncertainty (Track 3). Most interesting was understanding the WHISPER S/U approach and how it relates to the SCALE approach. Although I believe the SCALE approach is more mathematically rigorous and leads to greater insight on biases, the WHISPER system is undoubtedly easier to use and appears more conservative. There should be a more rigorous way to assess the performance of these two methods—and improve the ease of use for the SCALE approach.
09/17/19 afternoon	Attended Nuclear Data (Track 2). Highlights in this track were Luiz Leal's presentation of work on new evaluations for Gadolinium isotopes. This has considerable overlap between criticality safety and reactor physics and we will have a task in SCALE to evaluate the performance of this new data. Also the talk of a temperature effect on resonance uncertainties was interesting in understanding a temperature effect we are currently neglecting in the uncertainty representation.
09/18/19	Attended Measurements, Experiments, and Benchmarks (Track 4). Highlights in this track include new experiments (IER 209, TEX, BUCCX), which can provide SCALE with useful validation cases for both criticality safety and reactor physics. A method was presented for using cold criticals in a BWR for validation. The proposed ICSBEP benchmark based on TREAT has some significant composition uncertainties (hydrogen and boron in graphite) that should limit its applicability to code validation.
09/19/19 morning	Attended Measurements, Experiments, and Benchmarks (Track 4). Highlights in this track were the consideration of experiments at higher temperature and lower moderator density. These are extremely valuable for code validation.
09/19/19 afternoon	Attended workshop on "Enhancing Validation of Nuclear Criticality Safety Calculations with ICSBEP Handbook and NEA Tools". Gained an appreciation for the depth of capabilities of NEA tools, mainly in DICE, although the learning curve is quite steep. Also, the data used internally is sparse and outdated. There's a need for timely (ideally automated) update of the sensitivity and benchmark data. Also gained an appreciation for the enormous content of the ICSBEP handbook.
09/20/19	Worked from hotel in Paris, focusing on planning activities for NCSP and follow-up reading of ICNC papers.
09/21/19-09/22/19	Personal days.

OECD/NEA Headquarters, Paris, France (day-by-day agenda)

09/23/19 morning	Attended meeting of Sub-Group 4, Analysis of Past Criticality Accident. The majority of the time was spent presenting the Windscale Works Incident where unknown organic content in an aqueous solution tank caused an approximately 10-second criticality event. The event was particularly interesting in that it happened when new aqueous solution was added to the tank, which flowed through the organics, temporarily creating an emulsion of a specific shape that resulted in criticality. The criticality self-terminated as the emulsion settled. Discussion centered on the usefulness of the benchmark, ability for participants to model it, and necessary specifications. Does it require coupled fluid dynamics
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or should we impose a conic shape of the emulsion and ensure that codes predict this as a critical configuration? There are lots of missing details. After talking to others at lunch, the design of modern holding tanks (annular or long, thin) prevents this kind of incident and the remarkable amount of contaminants present makes it an interesting historical occurrence but not safety-relevant by current standards.

09/23/19 afternoon

Attended meeting of Sub-Group 3 on the effect of temperature on the neutron multiplication factor for PWR fuel assemblies, which includes analysis of new thermal scattering data for ice. Dennis Mennerdahl, Marion Tiphine, BJ Marshall, and Paul Smith all presented work from EMS, CEA, ORNL, and Wood, respectively. Sonny Gan of Sellafield coordinated and presented quite a few results, with the only outlier being a deterministic code submission. All evidence clearly indicates the density effect of ice vs. water trumps the temperature/scattering kernel effect significantly. Offline, I discussed with BJ Marshall that the test case chosen is not ideal for demonstrating the effect of ice data on simulations. We will create a small set of SCALE cases to show the effect more clearly.

09/24/19 morning

Attended meeting of Sub-Group 2, Blind Benchmark of MOX damp powders. The main purpose of this activity, as I understood it, was to investigate bias predictions with various tools for scenarios with little validation data, such as MOX damp powders. Although criticality in MOX damp powders is interesting, I would have suggested a different approach if bias prediction is the underlying goal. In my opinion, the ideal way to compare methods is to remove a single case from the validation set, treat that case as an application, predict the bias in that case from all others, and compare to the true bias.

The MONK team (Wood) had an interesting multi-category matching scheme for assessing similarity based on low/medium/high similarity rankings for 6 categories:

- Type of fissile material
- Non-fuel absorption
- Leakage
- Resonance absorption
- Fast fission
- Hydrogen content.

They are in the process of converting from low/medium/high to a number in [0,1]. The MONK team also has two tiers of validation inputs, a rigorously QA-ed tier and a kind of “initial QA performed” tier. I believe this is a good approach for validation suites, for example with VALID we have a very large cost to get something from ICSBEP into the suite. In many cases, I would prefer to spend 100K on new VALID cases and get 1 “class A” benchmark and 10 “class B” benchmarks versus 2 “class A” benchmarks.

This discussion led into the need to identify certain ICSBEP benchmarks as non-ideal for certain purposes, such as bias prediction or code validation, due to known issues. This resulted in a proposal (later accepted) for Sub-Group 8, led by Wieselquist at ORNL to better categorize benchmarks by usefulness for a

specific purpose and collect more information on ICSBEP benchmarks, especially from experts, to disseminate to the entire community.

09/24/19 afternoon

Attended meeting of Sub-Group 7 on the definition of a benchmark on sensitivity/uncertainty analyses on used fuel inventory. This benchmark had chosen a difficult-to-model sample from Gosgen where the fuel rod had been moved from one assembly to another in its 3rd cycle. The participants discussed how much modeling information to mandate in order that participants contribute comparable results. With fairly extensive experience in depletion validation, I recommended to do a simpler case as well as let participants choose modeling parameters to yield minimal extra calculation bias with respect to experimental uncertainty, according to their chosen codes and methods.

This sub-group will likely have 3 stages. In the current stage, the benchmark will be defined and a report produced. In the second 2-year period, a single depletion calculation will be performed. In the third 2-year period, the sensitivity/uncertainty calculation will be performed. This analysis should integrate somehow with SFCOMPO.

09/25/19 morning

I did not attend Sub-Group 5, Experimental needs for criticality safety purposes, as I thought I had seen most of it at ICNC. Instead, I caught up on SCALE-related managerial duties from the hotel.

09/25/19 afternoon

Attended Sub-Group 6, Statistical tests for diagnosing fission source convergence and undersampling in Monte Carlo criticality calculations. This was essentially the same content as the MCNP (LANL) talk by Forest Brown at the 2019 NCSP TPR and so I won't summarize here.

The MONK (Wood) methodology relied on a clever fission site convergence test where you check the nearest neighbors on successive generations and once the distribution of nearest neighbors converges, you declare the source distribution has as well. They also investigated differential entropy.

I believe SCALE needs to actively show more capability in this area. With criticality calculations, we give the user details on how results would change if you had chosen a different number of inactive generations. With this printout and other standard convergence checks, a novice CSAS user can easily avoid issues in k-eff results due to source convergence issues. However, for other tallies, e.g. flux/reaction rate, CSAS does not provide this type of information. Also, CSAS has fairly sophisticated starting sources, including one from a voxelized deterministic calculation constructed directly from the user-input geometry. This starting source should be as effective at accelerating source convergence as anything presented by Forest for MCNP, and it is available in the current 6.2.3 release. However, it is clear from Forest's talk that there are additional source convergence metrics that could be added to SCALE. In particular the meshing selection based on mean distance to fission seemed like a valuable automation.

09/26/19

I did not attend Sub-Group 1, Role of Integral Experiment Uncertainties and Covariance Data in Criticality Safety Validation. B.J. Marshall was attending and I am very familiar with this work and do not have much to contribute at this late

stage in the effort. Instead, I worked on the Sub-Group 8 proposal and other SCALE managerial activities.

09/27/19 Attended the WPNCS meeting where the various sub-groups were summarized, country update reports were given, the ICNC 2023 location was announced (Sendai, Japan), and the new Sub-Group 8 which I will lead was voted on and accepted.

09/28/19 Travel from Paris, France to Knoxville, USA

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